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# A Study on the Wear Properties of AA3003 Al Alloy using Green Lubricants with Graphite and $MoS_2$ Solid Additives

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**Abstract:** *In the present investigation 2 lubricants combinations were prepared by homogenously mixing graphite powder and molybdenum disulphide powder with canola oil. In order to optimize the result, lubricants were prepared by varying the percentage of additives within the base oil. This experiment is carried out in a pin-on-disc tribometer for friction and wears monitoring. The test is done by introducing different sample lubricants to the disc running against the AA3003 Al pin at an rpm of 500. As the percentage of additive increases up to 7% the wear rate of pin reduce and reaches an optimum value further increase in additive percentage shows an linear relation to wear rates.. Considering the cost effectiveness, every samples having $MoS_2$ additive is costly. And the samples, which containing graphite additives are less costly. Based on the experiment it was determined that a solid fraction of 7% additives was the optimum additive candidate for minimizing the friction at the condition tested The sample which containing 7% $MoS_2$ with canola shows best Tribological behavior. It reduce the wear rate of Al alloy to a great extend. And we have canola oil with 7% graphite lubricant which has the potential for use as industrial lubricant because of its cost effectiveness*

***Index Terms: Canola Oil, Graphite, $MoS_2$, SEM, Tribometer.***

## 1. INTRODUCTION

The main reason for energy loss in a mechanical system is friction which can be controlled by lubrication. In the absence of proper lubricants, contact between mating component increases which result in high level of friction and ultimately failure occur. Petroleum lubricants that used by industrial community have so many demerits .Due to the excess cost associated with disposing these petroleum lubricants, some efforts are made to develop lubricants from environmentally beneficial components. Selection of a good combination of a base-oil and proper additives is significant for effective lubrication. Many studies have been carried out on the application of solid additives in the field of lubrication. The reduction of friction and wear are dependent on the characteristics of additives such as size, shape and concentration. Many researchers report that the percentage of solid additives in the base-oils is an important parameter while formulating the lubricants. in most of the industries sheet metal stamping is considers as the primary stage of product creation. But it is identified that the sheet metal forming operation creates some environmental problems. Large quantity of grease and liquid lubricants wear used at the time of forming operation. So this creates some environmental issues. The ultimate motivation of the present work to prepare and test 2 environmental friendly petroleum free lubricants and find its potential in sheet metal forming process.

### 1.1 Lubrication properties of Solid Additives

Solid lubricants are dry lubricants which have been used alternative to conventional liquid lubricant. They have a lamellar structure with low inter layer friction. Powder lubricants have the ability to stick the surface to create a contact layer. Most advantage of using solid lubricants is they can be used at extremely high temperature. Molybdenum disulphide, graphite, tungsten disulphide are examples of some of the solid lubricant.

### 1.2 Lubrication properties of canola oil

Green lubricants are those lubricants derived from vegetables. Canola oil is considered as a green lubricant which is derived from rapeseed. The polar nature of canola oil makes good lubricant as they readily fasten to metal surface. One of the advantages of using canola oil are they processing uses less energy resulting in reduced emission to environment. Vegetable oils are much better than mineral oil and other petroleum based oil in reducing friction and wear. It also cleans sludge and dirt from the equipment being lubricated. Relatively high grades of mono saturated chain gives canola oil acceptable low temperature properties.

### 1.3 Properties of combines oil + solid additives

There is a lot of drawback in using dry solid lubricants in sheet metal forming and stamping operation that it must be continuously supplied between tool and work piece. Such a spray system is difficult to made and expensive to apply for this reason natural canola oil – solid additives mixture is used instead of conventional petroleum based lubricants. Here canola oil acts as a carrier for the third body particles. When it's come in contact with the metal interface, the mixture forms an additional layer on the lubricating surface and reduces excessive wear. The ultimate motivation for the present work is to test a environmental friendly lubricant using canola oil as base oil with graphite and $MoS_2$ as additives. To determine its potential for use in sheet metal forming and stamping processes.

### 1.4 Structure of Graphite Micro Powder

The surface morphology of the graphite micro powder was revealed through the SEM image shown in figure 1. It shows a homogeneous distribution of plate like particles. The layered structure of graphite allows sliding movement of the parallel graphene plates.

**Figure 1: SEM image of Graphite Micro powder**

### 1.5 Structure of $MoS_2$ micro powder

The surface morphology of the $MoS_2$ micro powder was revealed through the SEM image shown in figure 2. It shows a homogeneous distribution of hexagonal plate like particles.

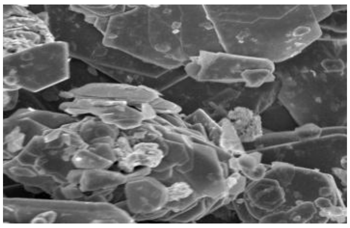

**Figure 2: SEM image of $MoS_2$ Micro powder**

## 2. EXPERIMENTAL WORK

### 2.1Material Selection

#### *2.1.1 Base Oil*

The work is usually done with green petroleum free oils. There are different types of vegetable oils available in the market. For the current work, the lubricant chosen is canola Oil.

**Table1: Properties of Canola Oil**

| Parameter | Value |
|---|---|
| Relative density(g/cm$^3$) | 914-917 |
| Viscosity | 78.2 |
| Specific heat(J/G at 20°C) | 1.910-1.916 |
| Thermal conductivity(W/Mk) | 179-188 |

#### *2.1.2 Graphite and molybdenum disulphide micro powders*

Graphite and molybdenum disulphide micro powders are solid lubricants that are extremely used in dry lubrication. The crystalline structure of graphite consists of hexagonal rings forming thin parallel plates. The graphemes are bonded to each other by weak Vander Waals forces. The layered structure of graphite allows sliding movement of the parallel graphene plates. Weak bonding between the plates helps in softness and self lubricating property of graphite. $MoS_2$ is also similar to graphite in appearance and feel. It is a silvery black solid that occurs as the mineral molybdenite the principal ore for molybdenum. All forms of $MoS_2$ have a layered structure, in which a plane of molybdenum atoms is sandwiched by planes of sulfide-ions. These mono layers are held together by weal Vander Wall force helps in easy sliding.

#### 2.1.2 *Pin*

The pin is manufactured using CNC machining. CNC machine was available at Industrial Estate, Trivandrum. The pin is made of AA3003Al alloy. The pin is having a diameter of 10mm and length 33mm.A total of 9 pins are needed for the experimentation of selected samples.

### 2.2 Test Samples

The lubricants samples were prepared by mixing additives with canola oil. Uniform mixing of lubricants were done using a ball mill. The mixing procedure is done in CSIR Trivandrum. All the 8 samples were prepared by varying the % additives in base oil. The samples to be tested are,

**Table 2: Samples for Experiment**

| Lube no. | Sample No. | Percentage of base Lubricant | Percentage of Graphite powder | Percentage of $MoS_2$ powder |
|---|---|---|---|---|
| C | C1 | 100% | 0 | 0 |
| G | G1 | 99.5% | .5% | 0 |
| | G2 | 97% | 3% | 0 |
| | G3 | 93% | 7% | 0 |
| | G4 | 88% | 12% | 0 |
| M | M1 | 99.5% | 0 | 0.5% |
| | M2 | 97% | 0 | 3% |
| | M3 | 93% | 0 | 7% |
| | M4 | 88% | 0 | 12% |

### 2.3 Experimental Setup

The experiment is carried out in a pin-on-disc tribometer for Tribological investigation.. The tribometer consist of hardened ground steel disc (High Carbon High Chromium Steel) having hardness 65 HRC, which is run against the pin of hardness 35 HRC. The disc is rotated by means of a motor and having 150mm diameter and 8mm thick. Tribometer can hold pins with circular and square cross section. The sensors connected in the machine calculate the frictional force and wear rate. The results are also plotted graphically in the connected computer. The test is done by introducing different sample lubricants to the disc running at a speed of 500 rpm. A dead weight of 5kg is provided.

**Figure 5: Pin-on-disc Tribometer**

## 3 RESULTS

The results are obtained directly from the Pin-on-disc tribometer. The wear track radius was set at 100mm in the tribometer. A dead weight load of 5Kg was applied for all the tested samples. The dick rotation was set to 500 rpm and the test was carried out for a time period of 3600 seconds .The computer connected with the pin on disc tribometer gives the plots for wear rate and frictional force with respect to time. A Scanning Electron Microscope is used to analyze the wear surface of pin at higher magnification. Weight of the pin is taken before and after the experiment for finding out the wear volume at different lubrication condition.

### 3.1 Sample C1: 100% Canola Oil

The first sample was selected for the validation test. The sample was composed of 100% canola oil with no additives. from the graph it is clear that there is a uniformly increasing of wear loss for a period of 1500seconds. After 1500 seconds the wear rate increases slowly and reaches a max value of 1017 micrometer at the end of 3600 sec. It is observed that the frictional force also reaches a constant value of 5.49N after a time period of 1500 seconds.

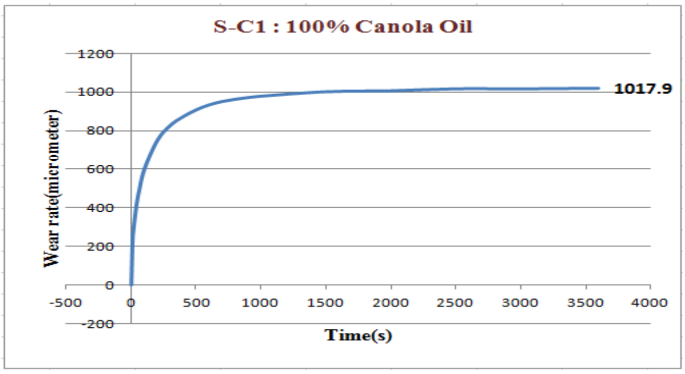


Figure 6: Wear Vs Time of Sample C1

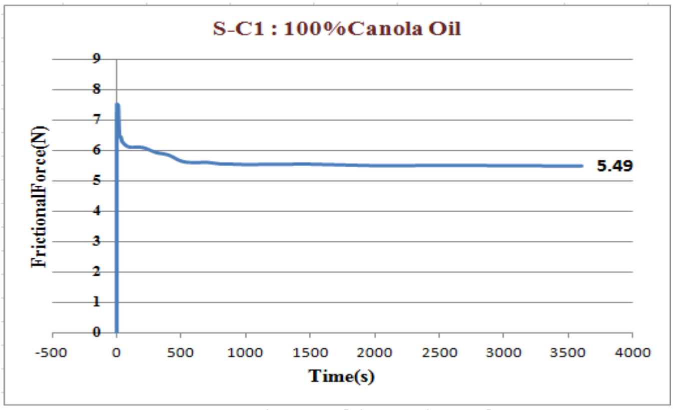


Figure 7 frictional force of Sample C1

## 3.2. SampleG1: Lubricant Containing 0.5% Graphite

The second sample was made of 99% canola oil and 0.5% graphite by weight. The presence of additives reduces the wear considerably. The wear rate reaches its maximum value of 921 micrometers after a running time of 1600sec seconds as shown in figure 8. The frictional force also reaches a stable value of 2.54N after 1600 seconds. The frictional force is considerably reduced from sample 1.

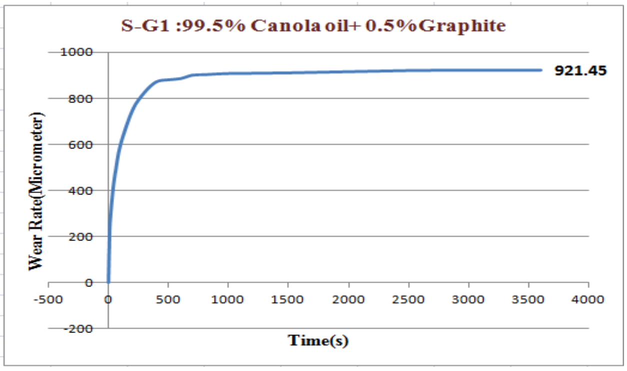


Figure8: Wear Vs Time of Sample G1

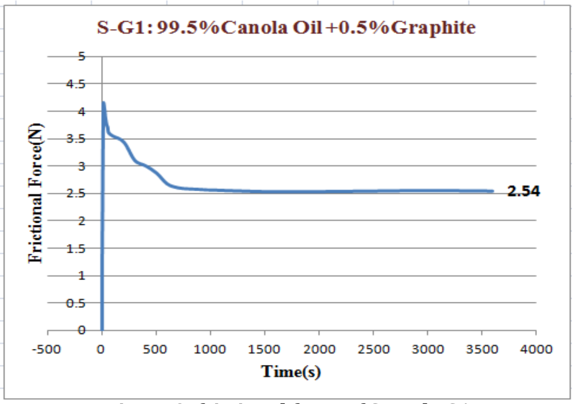


Figure 9: frictional force of Sample G1

## 3.2 Sample G2: Lubricant Containing 3% Graphite

In sample G2, 3% graphite is mix with canola oil. The result of wear loss is obtained to be uniform after 1500 seconds of running time and its value is 643 micrometers. The frictional force also reached its optimum value after 1400 seconds of running time and reaches a valued of 1.95N. The SEM analysis proves that there is a reduction in wear than previous samples.

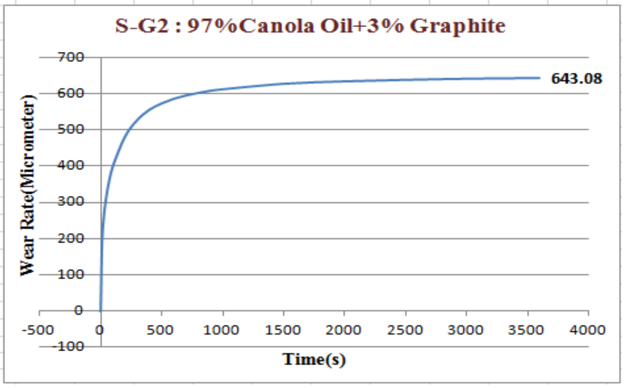


Figure 10: Wear Vs Time of Sample G2

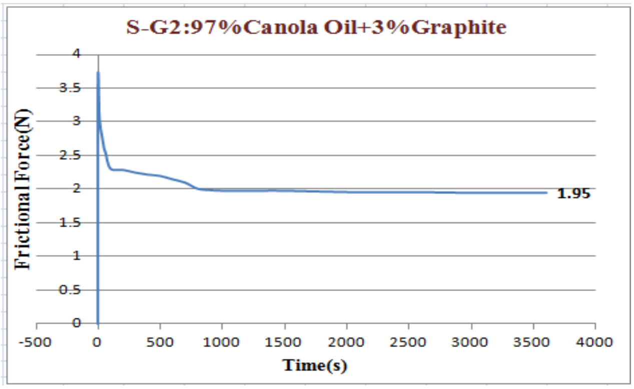


Figure 11: frictional force of Sample G2

### 3.4 Sample G3: Lubricant Containing 7% Graphite

Sample G3 is combination of 7% graphite and canola oil. This sample provides the least wear loss among other samples. After a running time of 1000 seconds the wear loss becomes a constant value of 350 micrometers and frictional force touches a constant value of 1.65N, which are the best among the previous.

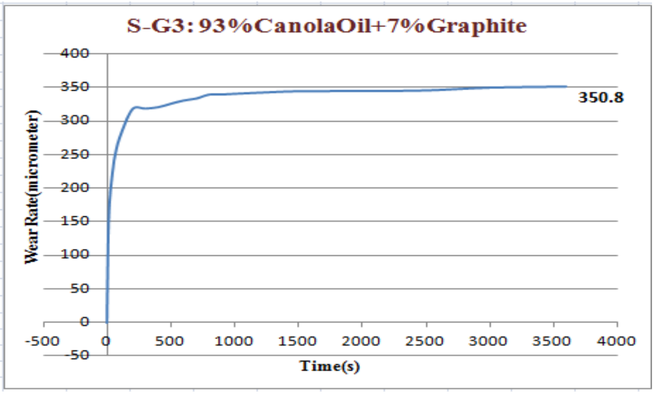


Figure 12: Wear Vs Time of Sample G3

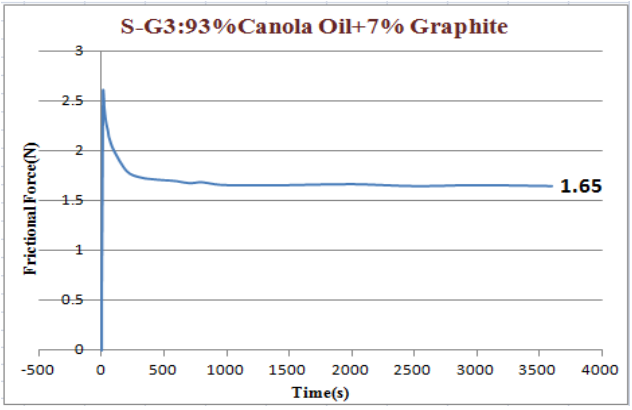


Figure 13: frictional force of Sample G3

### 3.5 Sample G4: Lubricant Containing 12% Graphite

SampleG4 contains 12% graphite mixed with 88% oil. The wear and frictional force becomes stable after a running time of 1200 seconds. The maximum wear is noted as 380 micrometers which is higher than sample G3. This may be possibly due to the higher percentage of additive in the sample. Also the frictional force is also higher than sample G3 and is recorded to be 1.82N after being stable. stuck in between the track and leads to further material removal.

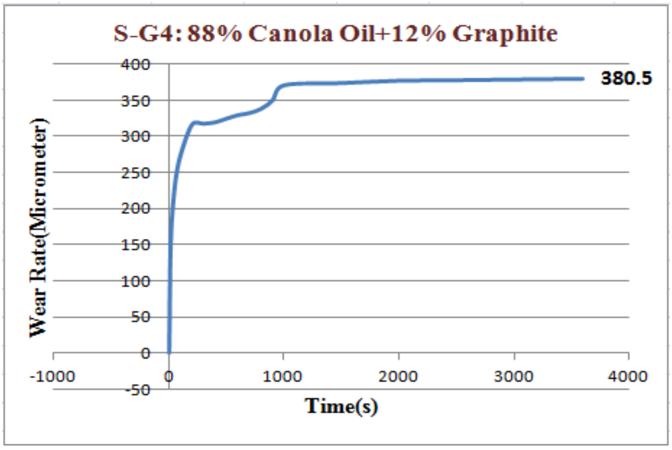


Figure 14: Wear Vs Time of Sample 5

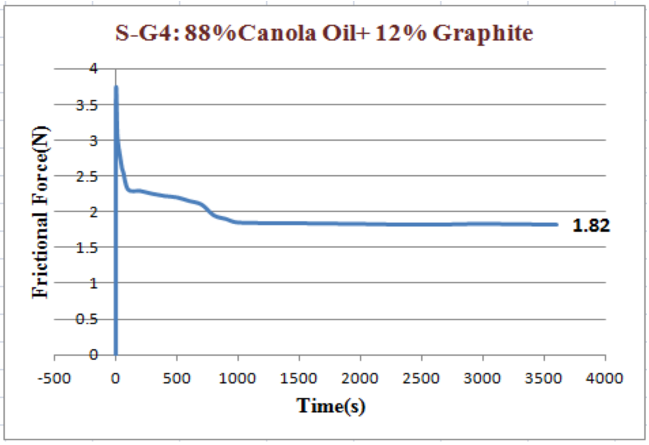


Figure 15: frictional force of Sample 5

### 3.6 Sample M1: Lubricant Containing 0 .5% $MoS_2$

The sample M1 is composed of .5% MoS2 in, 99.5% of canola oil. Figure 16 shows the wear loss plot to time. The wear rate reaches a value of 381 micrometer in a period of 1000 sec. The frictional force gets stable after 1000 seconds and is noted to be 1.82N which is seen from figure 22 which is a plot between frictional force over time.

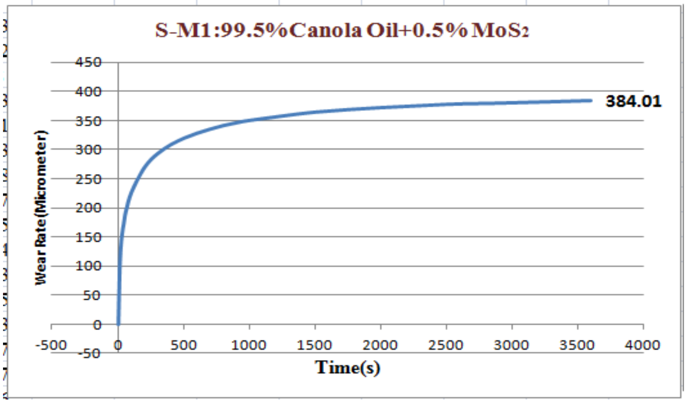


Figure 16: Wear Vs Time of Sample M1

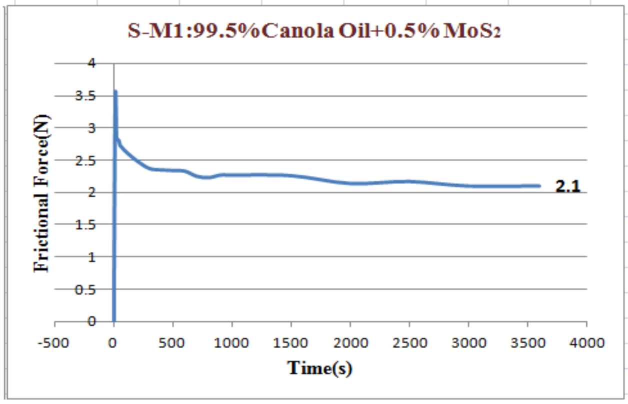


**Figure 17: frictional force of Sample M1**

### 3.7 Sample M2: Lubricant Containing 3% $MoS_2$

Sample M2 contains 3% graphite mixed with 97% oil. The wear and frictional force becomes stable after a running time of 1200 seconds. The maximum wear is noted as 310 micrometers which is lesser than sample M1. This may be possibly due to the higher percentage of additive in the sample. Also the frictional force is also lower than sample G1 and is recorded to be 1.81N after being stable.

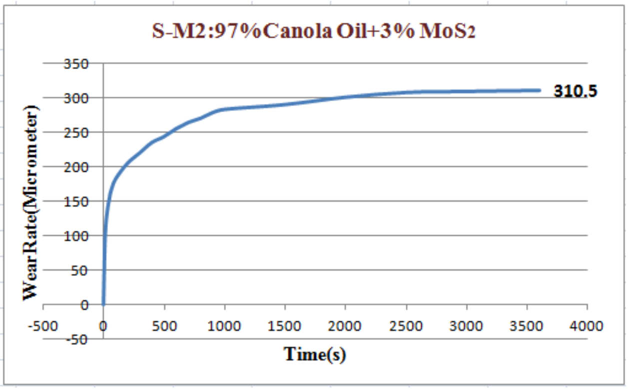


**Figure 18: Wear Vs Time of Sample M2**

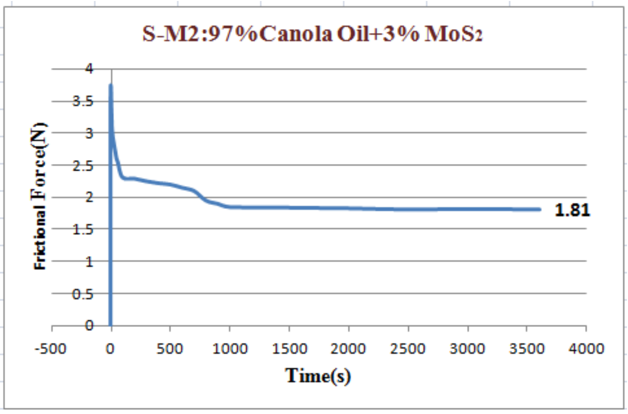


**Figure 28: frictional force of sample M2**

### 3.8 Sample M3: Lubricant Containing 7% $MoS_2$

Sample M3 containing 7%MoS2 in 93% canola oil. Wear rate reaches a value of 251.5 micrometer after a time period of 1400 sec and frictional force gives a constant value of 1.58.compared to previous samples M3 gives the least wear rate.

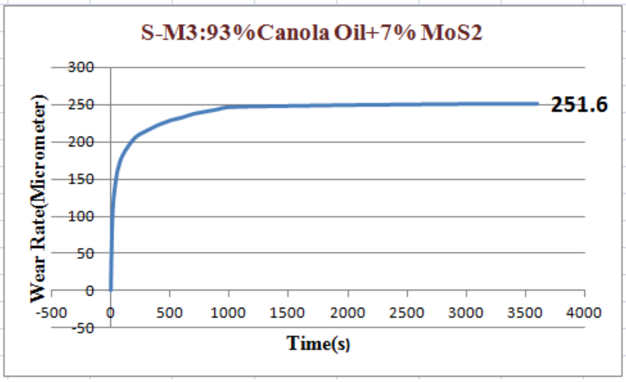


**Figure 20: Wear Vs Time of sample M3**

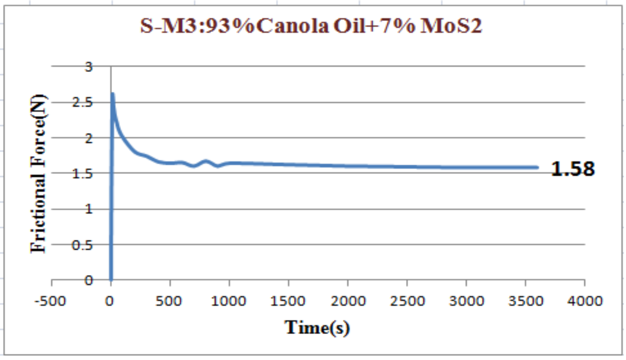


**Figure 21: frictional force of sample M3**

### 3.9 Sample M4: Lubricant Containing 12% $MoS_2$

12% MoS2 is mixed with 88% canola oil to prepare sample M4.due to the excessive amount of $moS_2$ in oil the wear rate slightly increases to a constant value of 284 after 1300 sec and frictional force reaches a value of 1.62

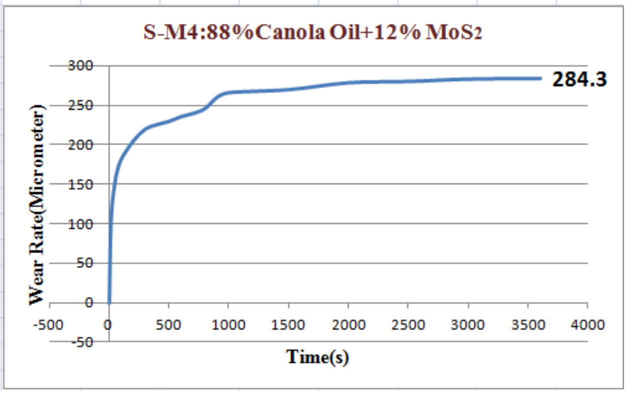


**Fig 22: Wear Vs Time of sample M4**

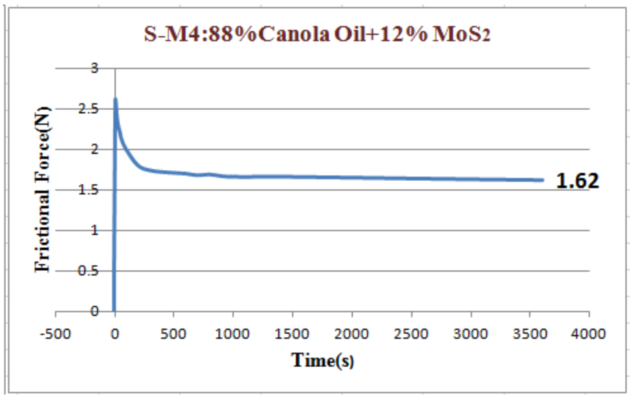


Figure 23: frictional force of sample M4

## 4. CONCLUSIONS

This work aims at compare the wear rate and frictional force of AA3003 Al Alloy using a novel lubricant with additives. 9 different samples with canola oil as the base medium is prepared for testing. The tests are done using a pin- on-disc tribometer. Tribological parameters are obtained from the friction and wear monitor attached to the tribometer.

The Sample M3 which constitute of 7% $MoS_2$ mixed to canola oil shows the best Tribological behavior. It enhances the frictional force behavior and reduces wear to a great extend comparing to sample C1, which is additive less lubricant. Considering the cost effectiveness, sample G3 which contain 7%graphite in canola oil is much better and shows close Tribological characteristic to sample M3.

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